EDGE2D/EIRENE simulations of the W event after X-point formation with the new JET-ILW

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* See the Appendix of F. Romanelli et al., Proceedings of the 24th IAEA Fusion Energy Conference 2012, San Diego USA

INTRODUCTION

Early in the 2011-12 JET ITER Like Wall (ILW) campaign, large tungsten (W) spikes were observed within 400 ms after the X-point formation. The influx of W from the W divertor during this period can lead to significant changes on the evolution of the current profile and, in two extreme cases caused even disruptions. Although it was possible to reduce the occurrence of these events by 30 % and minimize the impact on the plasma during the campaign, it is important to understand the physics behind the peaked W release and to find a way to avoid them in the first place. In this paper, EDGE2D/EIRENE [1,2] is applied to reproduce this transition phase with strong W release and to compare it with experimental observations.

EXPERIMENTAL OBSERVATIONS

A representative case (JPN 80295) with a peaked W release during the X-point formation is shown in fig. 1.

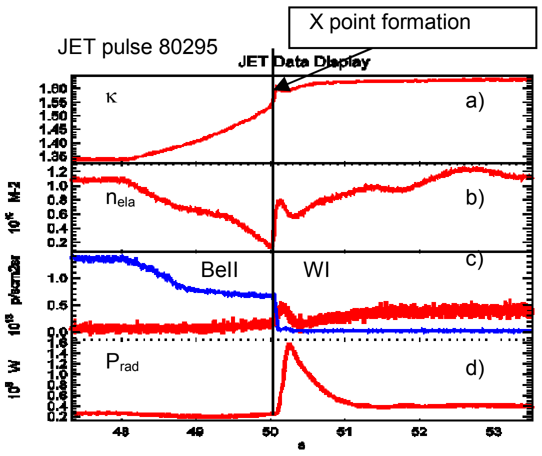

Figure 1. Experimental time traces of: a) elongation; b) core line integrated density; c) line intensities of BeII (528nm) at the horizontal plane (blue) and the WI (400.90nm) line intensity at the OT (red); d) the power radiation during the X point formation of the JET pulse 80295

- The peaked W influx can be described as follows: during the limiter phase, Be sputtering at the limiters occurs and is leading to a high c_{Be} in the main chamber plasma [3]. This enriched Be plasma reaches the divertor region during the X-point formation and the impinging Be ions are causing the W sputtering. The divertor plasma in this case is hot and thin providing high impact E_{Be}.
- A database of 1957 discharges showed in 1507 cases the W release in the transition phase.
- Peaked W release is not observed for plasmas with low c_{Be}, characterised by Z_{eff}<1.5, fig. 2.
- Plasmas with n_{eav}>5.3e19 m^{-3}, thus low T_e and in the consequence also low E_{Be}, show no appearance of the peaked W release, fig. 3.
- No clear correlation between the W source, represented by the WI, and P_{rad} in the centre has been identified. The actual WI is function of the neutral W, but needs conversion factors (which depend primarily on Te) to provide the sputtered flux [4], fig. 3.

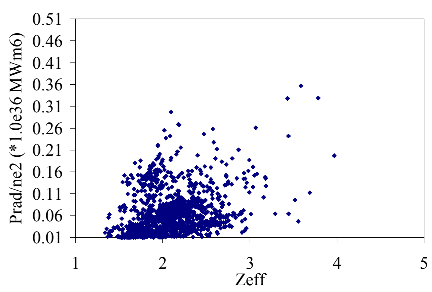

Figure 2. *Core W spike radiation loss normalised by ne2 for plasmas were the event was clearly observed as a function of the max core Z_{eff} during the 0.5 s before the X-point formation.*

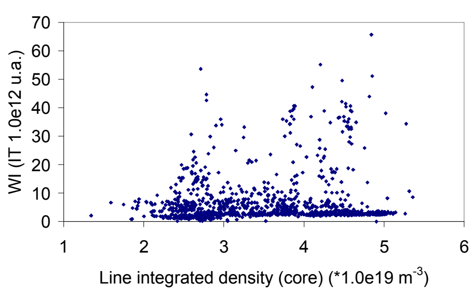

Figure 3. *WI (400.9 nm) line intensity at the inner target as a function of core line integrated density.*

EDGE2D/EIRENE SIMULATION SET UP AND PROCEDURE

- The radial direction the transport coefficients were assumed to be purely diffusive and were defined at the outer mid plane (OMP), see fig 5 [5].
- To simulate the observations during the X-point formation with EDGE2D/EIRENE, a two-step strategy was developed:

1. W sputtering at the targets by D or Be is suppressed, and a Be source from the main chamber wall is introduced mimicking enhanced sputtering run-by-run from the factor of 1 to 40. This lead to a variation in C_{Be} from 0.7% to 17.0%.
2. W sputtering at the plates by D and Be is activated, while reducing the main chamber Be source to those predicted by physical sputtering of Be due to D atoms.

- To simulate the different electron densities and temperatures observed experimentally a scan in $n_e(a) = 1.2\times10^{19}$ m^{-3} to $n_e(a) = 2.4\times10^{19}$ m^{-3} and power from 2 MW to 8 MW

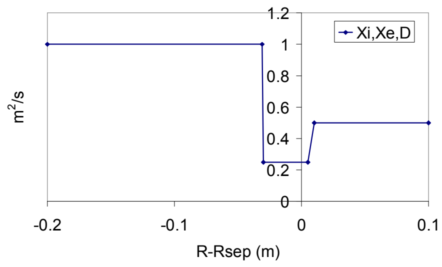

Figure 5. *Radial transport coefficients at the OMP used in EDGE2D/EIRENE simulations*

- The time evolution of synthetic diagnostics for the WI and BeII line intensities from one of the EDGE2D/EIRENE simulations are qualitatively in agreement with experiments, fig 6.
- Experimentally P_{rad} increases after the X-point formation (see fig. 1) while in the simulation it decreases. In the EDGE2D/EIRENE simulations the plasma is already in X-point configuration, a significant contribution of radiation from Be is observed during the higher Be sputtering phase.

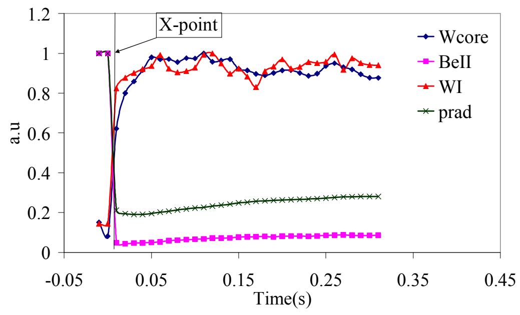

Figure 6. *a) Time evolution of the syntetic diagnostic normalised by its maximum from the VUV core W15-25 line intensity feature (blue), the outer divertor WI (red) line, the horizontal plane BeII line (pink) and the total radiation (green)*

- The c_W in the computational domain increases with c_{Be} for the same input power of 1.0 MW (for ions and electrons). c_{Be} decreases with Γ_D for a constant Be yield which lead to a more significant decrease of c_W due to less impinging Be ions to the target, fig 7.
- Both the presence of Be ions and their E_{Be}, reflected by Te in the divertor is an important factor for the W sputtering at the divertor plates, fig 8.

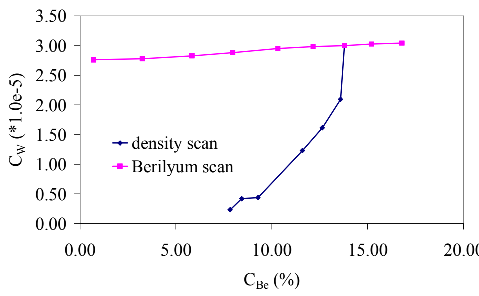

Figure 7. *W concentration in function of Be concentration. c_{Be} for the same $n_e(a)$ and increasing Be sputtering yield factor (pink line) and for the same sputtering yield factor and increasing density*

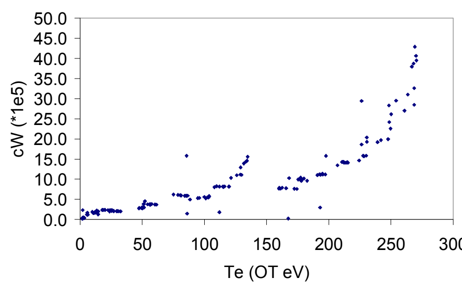

Figure 8. *W concentration in function of inner target electron temperature*

CONCLUSIONS

Although it was not possible to mimic completely the transient phase with change of the magnetic configuration from limiter to divertor configuration, it is possible to explain with the EDGE2D/EIRENE simulation the W sputtering source which occurs during the X-point formation. The W source is mainly caused by Be ions impacting on the W target plate. In the EDGE2D/EIRENE simulations no significant increase of c_W with the Be sputtering yield but with the n_{eav} which is inverse proportional to T_e if pressure in preserved. T_e at the divertor plate reflects the impact energy, hence E_{Be} on the W source. This was observed experimentally by increasing the Γ_D which minimised the impact of the peaked W source and even removing it completely in the later phases of the campaign

ACKNOWLEDGEMENT

This work was supported by EURATOM and carried out within the framework of the European Fusion Development Agreement. The views and opinions expressed herein do not necessarily reflect those of the European Commission and IST.

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